Evaluation of the climate for conservation of the adoration of the mystic lamb in the St. Bavo Cathedral in Ghent

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SUMMARY:
The purpose of this research was to study the indoor air conditions in the Saint Bavo Cathedral of Ghent, Belgium. The cathedral is well-known for the painting "The Adoration of the Mystic Lamb", originally placed in the Joost Vijdt chapel and moved later on to the baptistery into a climate chamber. Samples inside and outside the church were taken in winter and summer 2010. Further investigation involved the monitoring of the indoor climate of the cathedral to find measurements to improve the retention of the painting. This paper also gives a brief overview of heat and moisture modelling using TRNSYS, a multi-zonal model, which can be used in further research to approve the climate chamber.

1. Introduction

Already for centuries artistic wealth is kept in unheated buildings and they preserved well. The thick walls which are typical for historic buildings like the cathedral alleviate the fluctuations of air temperature and relative humidity.
Ghent University was commissioned to investigate the climate inside the baptistery and inside the climate chamber of the Saint-Bavo Cathedral at Ghent, where the painting "the adoration of the mystic lamb" by Jan van Eyck is currently being held (Fig.1). The famous artwork is an oil painting dyed on wooden panels, made in 1432. Work of arts made of moisture-containing materials sensitive to variations of thermal and humidity conditions, like wood, have adapted over the centuries to the local natural climate. This adaption might have involved a certain degree permanent change, as deformation or fracturing.(Bratasz et al. 2007)

FIG. 1: The adoration of the mystic lamb, painted by Hubert & Jan Van Eyck

The oil painting was originally placed on the altar in the Joost Vijdt chapel, but was moved in the ‘80 to a climate chamber, constructed in the baptistery. (Fig.2a) This area is divided into two parts by the construction of a suspended ceiling, which forms a protection against the daylight and also a closing of the cathedral by fire. The baptistery has a total length of 9,5m and maximal width of 8m. The church walls at the baptistery are made of sandstone. The area is divided into two parts by the construction of a suspended ceiling, which forms a protection against the daylight and also a closing of the cathedral by fire. At the moment, there is no heating system in the church and the baptistery.

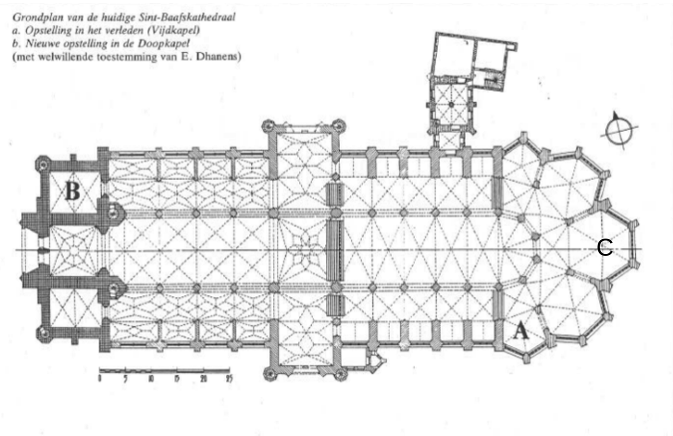

FIG. 2a: Floor plan of the Cathedral of Saint-Bavo (A) Vijdt Chapel, (B) baptistery, (C) sacrament chapel.

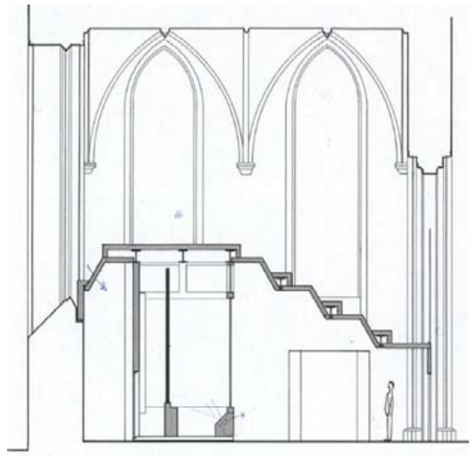

FIG. 2b: Cross section of the baptistery with the climate chamber.

2. Measurements

The current variation in temperature en relative humidity (RH) inside the shrine causes dimensional changes in the wood. For a painting on a wood support, these changes can weaken the adhesion between the paint and/or ground layers and the wood support, resulting in paint loss.(Sozzani 1997). Therefore from February till November 2010, the temperature and relative humidity (RH) were measured in the St. Bavo Cathedral. Initially loggers have been placed at six locations in the building (indicated on Fig.2b):

1. in the church above the entrance hall
2. in the baptistery
3. in the space above the baptistery
4. top of the climate chamber
5. bottom of the climate chamber
6. In the Sacrament Chapel (Fig.2a)

The global results are given in Fig.3. The ambient temperature varies between -5°C in February 2010 and 25° C in summertime. The temperature in the church, sacrament chapel and above the baptistery is nearly the same and varies between 2°C and 25°C. Daily temperature fluctuations are not larger than 2°C. The measured temperatures in the baptistery and in the climate chamber also run parallel. In the baptistery, temperatures range from 6 °C to 25 °C. The measured temperature at the top and bottom of the cage is almost identical, and ranges from about 6 °C and 20 °C. This indicates that the air inside the cage well mixed.

The first period, the baptistery was not closed to the public. Due to the visitors and the lighting, the average temperature in the baptistery is about 3°C higher than in other parts of the church. Late April, when this part was closed to the public, the temperature in the baptistery and the climate chamber became similar to other spaces in the church. The lighting in the climate chamber is reduced on May 30 and June 6. (Fig.4), but this has no noticeable effect on the average temperature in the shrine.

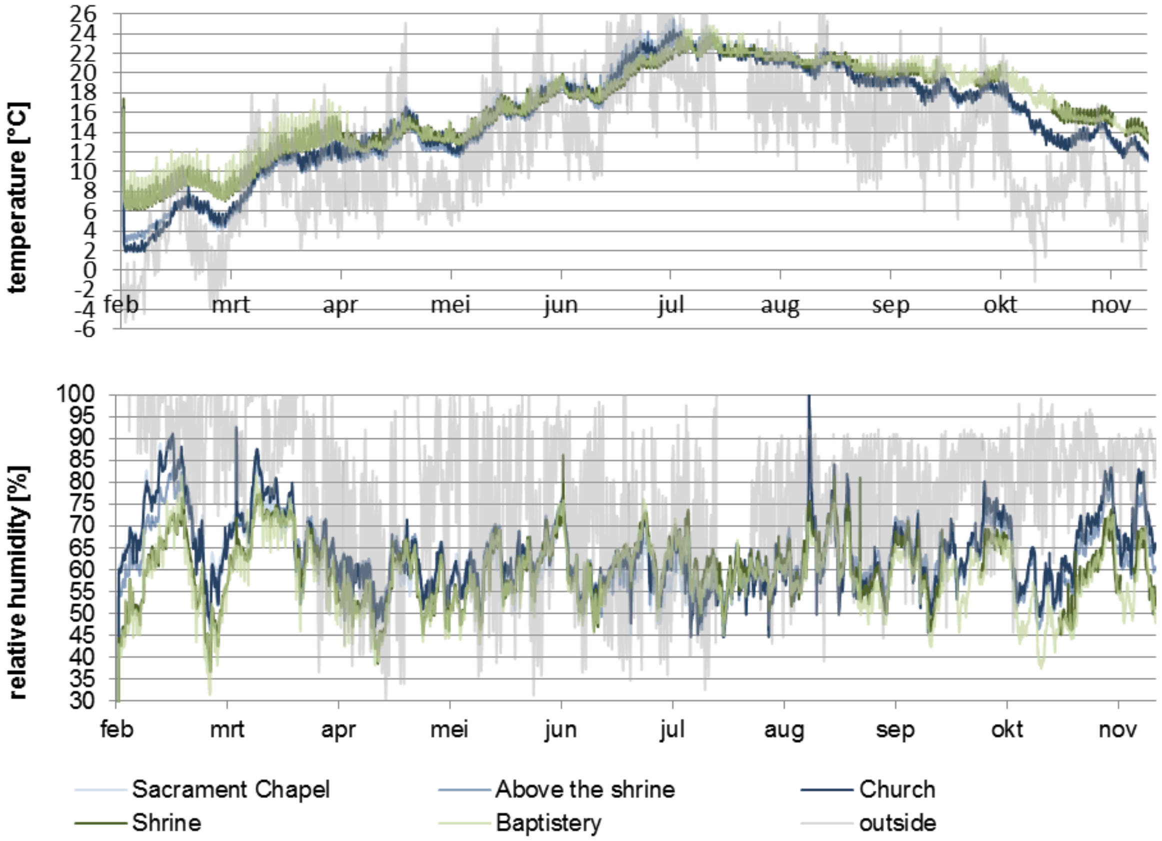

FIG. 3: Measured temperature and relative humidity (11/02/2010 -31/11/2010)

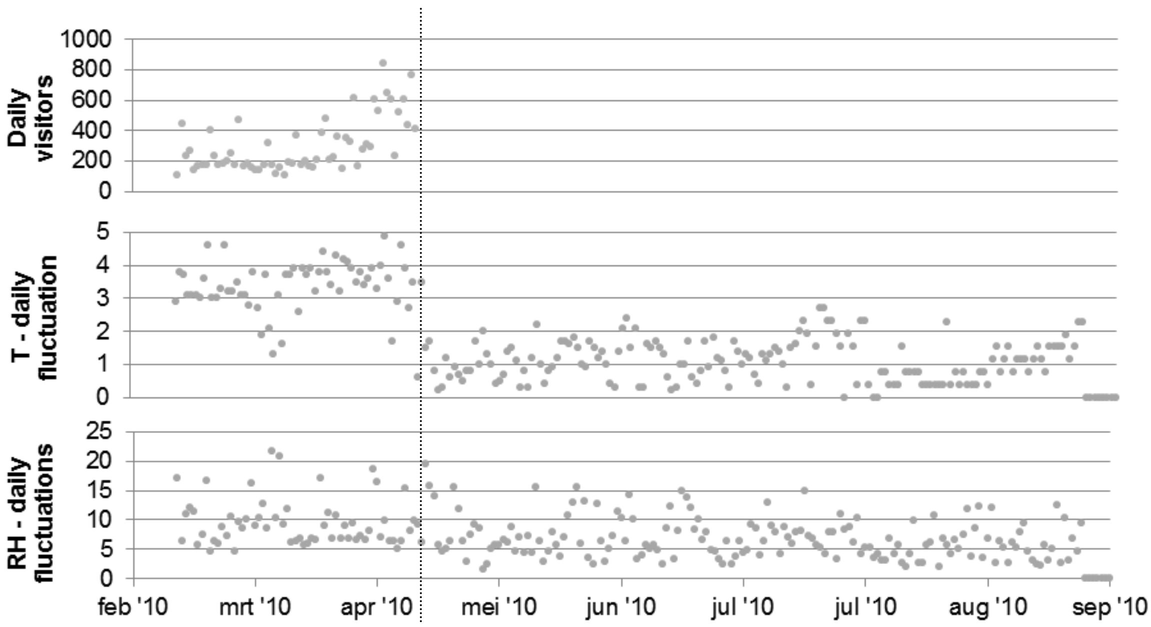

FIG. 4: Effect of the visitors in the baptistery on the temperature and relative humidity

Because this is an historic building, the indoor climate results of the shrine are analysed with an reverse ASHRAE method proposed by Martens et al.(Martens, Schellen & Ankersmit). The yearly average in the climate chamber measures 16°C and 60%RH. The climate is analysed for the Class A*. (Table1) For this class allowable amounts of daily fluctuations are ±5% RH and ± 2 ° C at the current average. A seasonal adjustment up or down 10% RH, and up 5°C, down 10°C on the yearly average is permitted. The temperature conditions are satisfied for 75% of the time, for the relative humidity only 30% of the measured data lies within the allowed fluctuations.

TABLE 1: Daily fluctuation of the RH and temperature measured in the climate chamber (11/02/2010 -21/09/2010).

	$\Delta T \leq 2°C$	$\Delta T \leq 5°C$
[RH –5%, RH+5%]	19,55%	3,35%
[RH –10%, RH+10%]	35,75%	11,73%
ΔRH >10%	22,35%	7,26

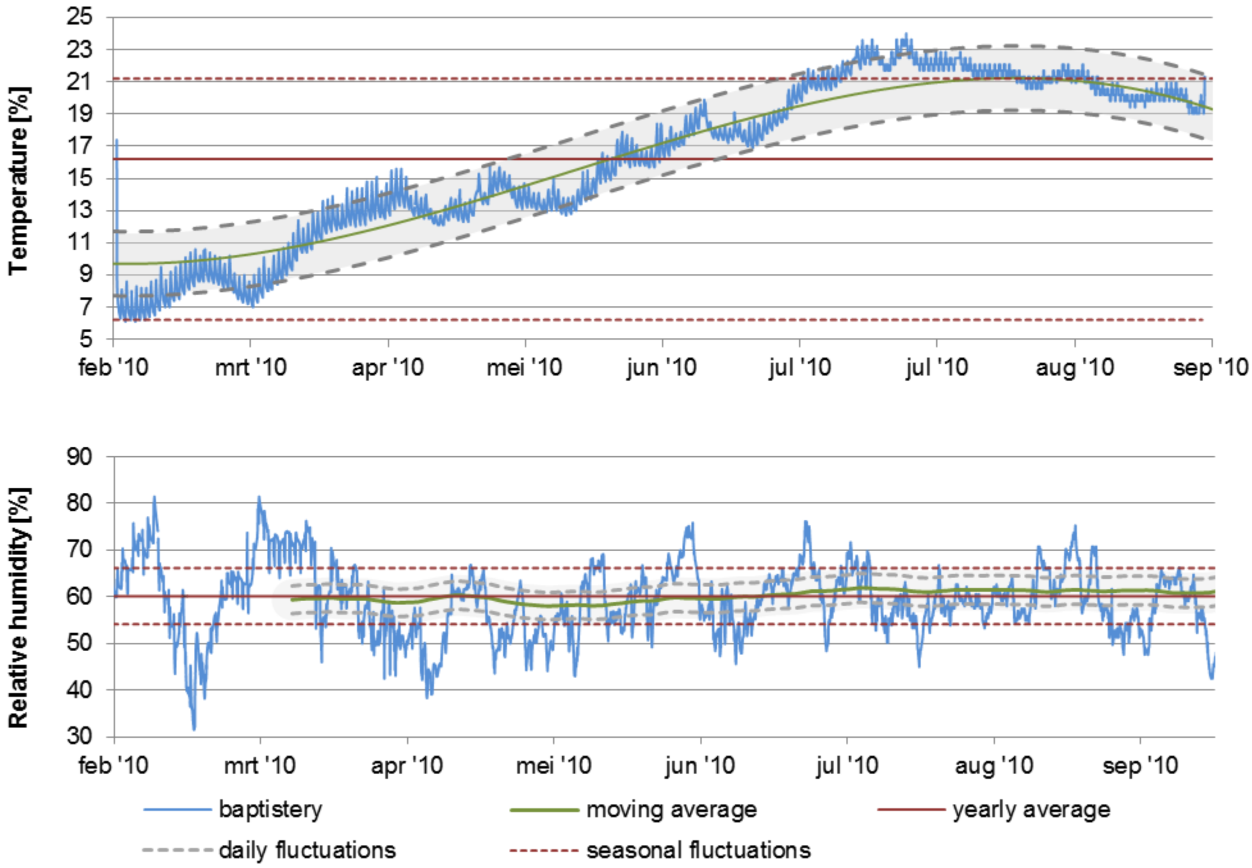

FIG. 5: Reverse ASHRAE method (Martens, Schellen & Ankersmit)

3. Modelling Temperature and Humidity with TRNSYS

A simulation with the multizone software TRNSYS was performed. The hourly values of the ambient temperature, the temperature of the church and the space above the baptistery were used as boundary condition. The baptistery and the climate chamber are two internal zones. Visitors are allowed from 8:30 till 17:00 and the number varies by day.

The baptistery was raised between 1462 and 1534. This part of the church is built in the Belgian Ledian sandstone. This building brick was during the15th and 16th century a very popular building material in West Brabant and the Flanders. The stone was often use for renovation in town and can be described as a sand- limestone to calcareous sandstone. The shrine is constructed in 1986 and is made of glass with a thickness of 34mm, placed in a steel frame. The material properties of the used materials are based upon the values proposed by the IEA(Kumar 1996) and are shown in Table 2. ISO/FDIS 13370:2007 is used to calculate the heat losses via the ground.

TABLE 2: Characteristics of the Belgian Ledian Stone (Kumar 1996)

	Glass	Steel	Sandstone	Concrete
ρ [kg/m^3].	2500	7800	2000	2500
c [J/kgK]	0.84	0.51	0.84	0.84
λ_d [W/mK]	1.4	0.85	1.0	1.9
μ [-]	∞	∞	25	37-200

ρ Density of the dry material
c Heat capacity
λ Thermal conductivity of the dry material
ψ Porosity

In order to calculate the climate in the baptistery the air flow through the baptistery and the shrine is estimated by a tracer-gas leak testing method. From these measurements, an airtightness of 0.33 ACH was derived when the climate chamber was closed, and a tightness of 1.85 ACH for the shrine while the door was opened. In a second test, the tracer-gas was injected into the baptistery where the climate chamber is placed to judge the leak flow to the rest of the church and the space above. The calculated leak flow for the baptistery measured 0.48 ACH.

Figure 6, 7, 8 & 9 show the results calculated with TRNSYS. The simulation of the current climate illustrates that the temperature fluctuations in the baptistery and the climate chamber are mainly produced by the daily visitors. During the period the visitors were not allowed, the daily variation is caused by the presence of renovation specialists and the lightning, although the part of the lightning is small. Correspondingly an increase in the absolute humidity is caused by the attendance of the tourists. Also an amount of the oscillation is caused by cooling down along the concrete ceiling.

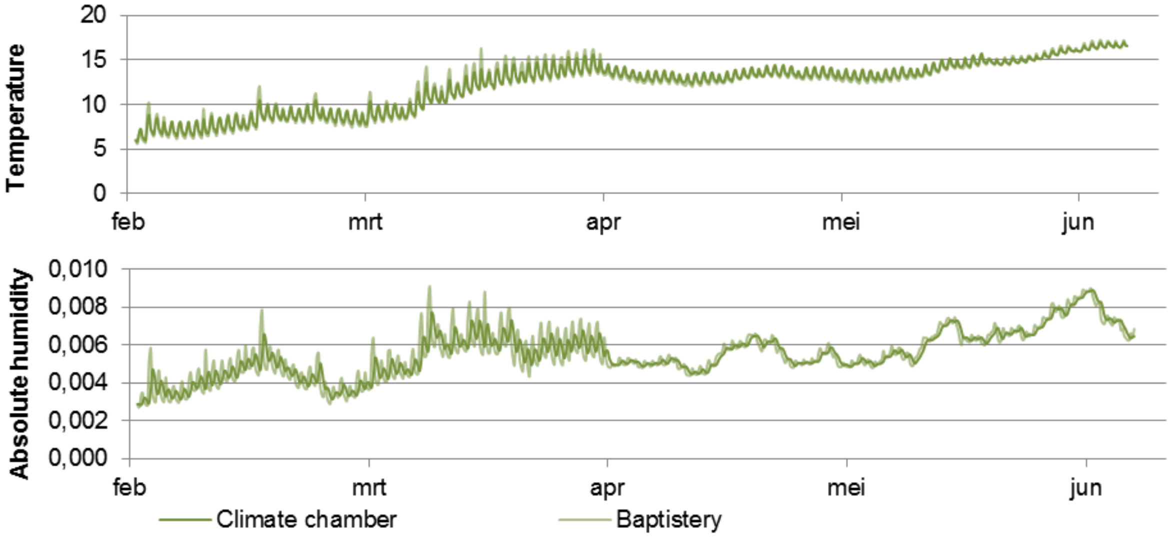

FIG. 6: Simulated temperature and absolute humidity of the climate chamber and baptistery with TRNSYS.

The long-term fluctuations of temperature and humidity are affected by the outside climate. Sinking the air leakage to the church would reduce the fluctuation. (Fig. 7) Therefore, a lock between the church and the baptistery is constructed in November 2010.

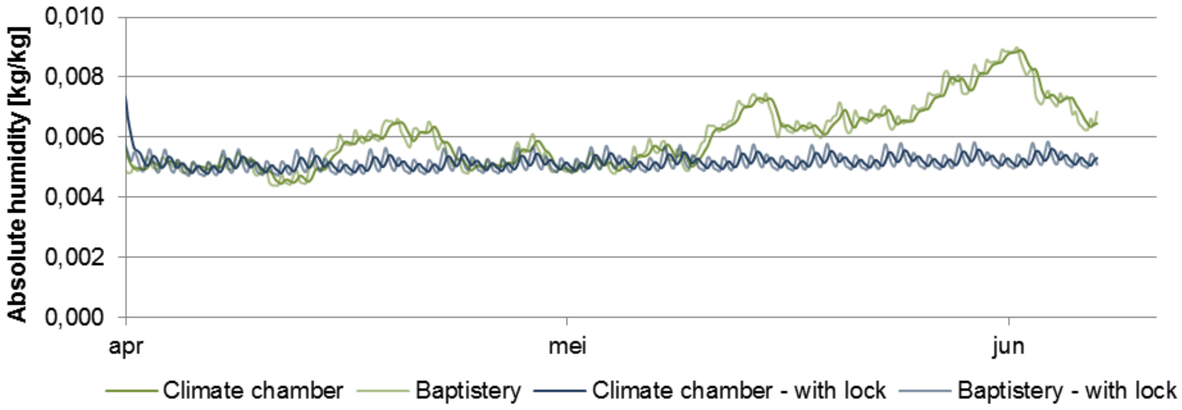

FIG. 7: Comparison between the simulation of the absolute humidity with and without an air leakage to the church.

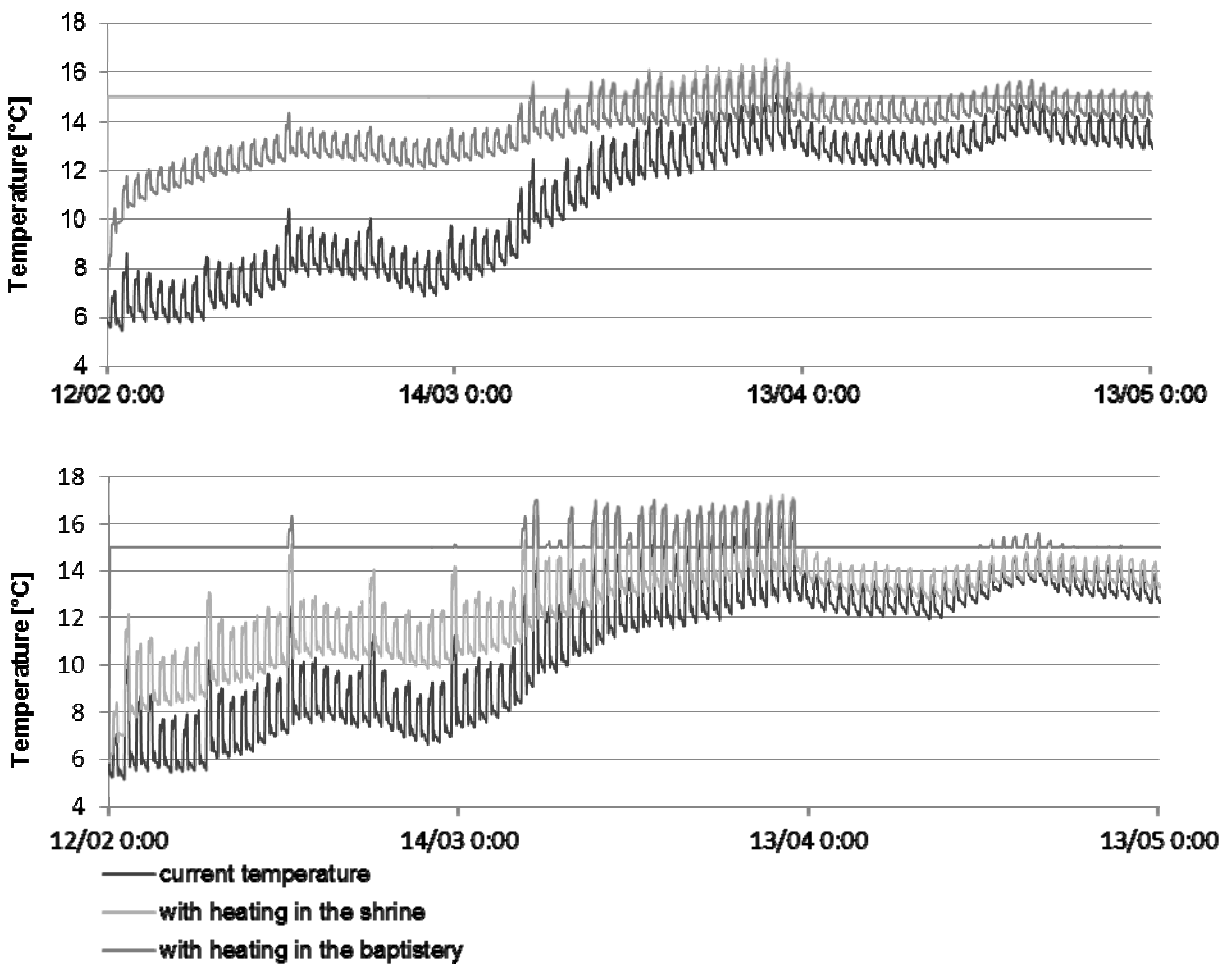

FIG. 8: Comparison between the simulation of the temperature in the shrine (a) and the baptistery (b) with heating in the shrine or the baptistery.

Also, the temperature is too low in winter season. For that reason, a simulation with heating and cooling was performed. (Fig. 8) These results illustrate that heating the baptistery is a clear influence on the temperature fluctuations in the shrine. The mean temperature for both situations is set on 15°C. Because the visitors are the main reason of the fluctuations, heating at night is necessary to set off the temperature drop. Furthermore a comparison is made of the heating demand when the heating is placed in the shrine or in the baptistery. (Fig. 9). When the heating is placed in the shrine itself the variation in temperature and heating demand remains restricted, but further investigation is needed to study the effect of the air flow.

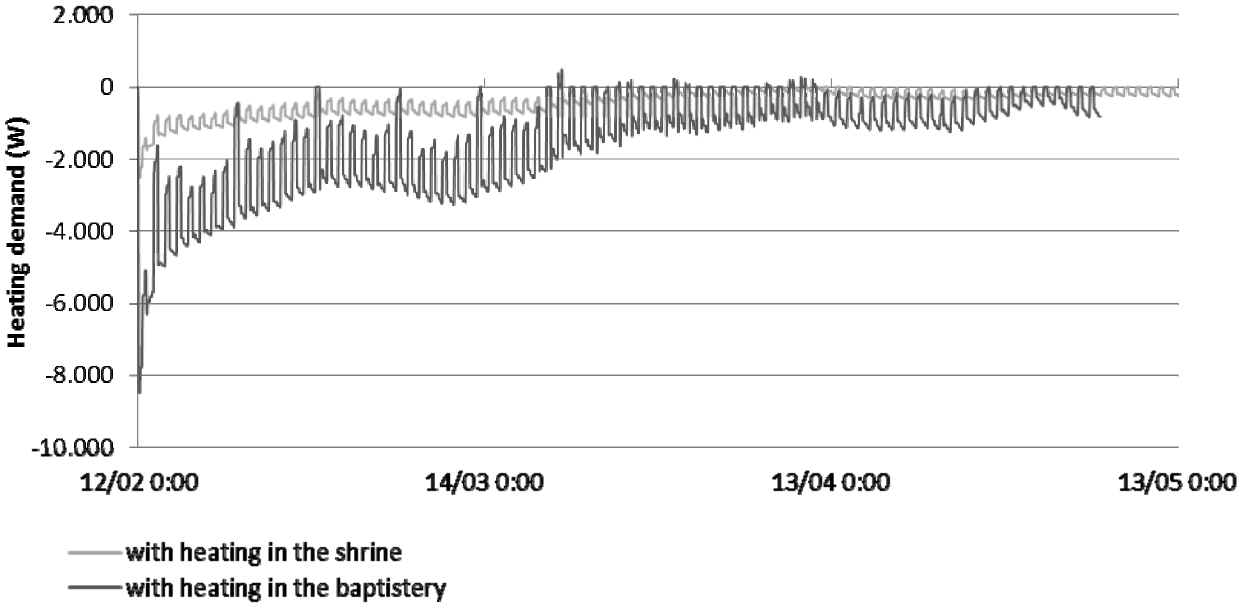

FIG. 9: Comparison between the simulation of the heating demand with heating in the shrine or the baptistery.

4. Conclusions

The presence of visitors shows a significant effect on the daily temperature variations in the baptistery. However, the influence on temperature variations in the climate chamber remains rather limited. Equally an increase in vapour pressure can be observed during the period when visitors are allowed. There are two possible reasons: first, an air leakage between the climate chamber and the baptistery in which visitors produce a certain amount of water vapour and second by fluid release (evaporation) by the wooden panels of the painting if the temperature rises in the climate chamber. Given that the temperature in the cage rises when no visitors were present (Fig. 3) and at that time no increase in vapour pressure was observed, we can conclude that mainly the visitors caused the increase in absolute humidity in the baptistery and in the climate chamber. This is also confirmed with the simulation performed with TRNSYS.
The air leakage of the baptistery to the climate was measured using a tracergasmeting and varies between 0.32 and 0.45 air changes by hour. During a visual inspection of the cage was also noted that many air leaks were present.

An analysis of the climate in the cage indicates that the maximum limit of 75% RH for a good preservation of the painting sometimes was exceeded. For an ideal climate, the RH must be lie around 60% RH. Secondly, the temperature is also important, in theory it lies between 15°C and 5°C. The current measurements showed that daily temperature variations are almost smaller than 5°C and the daily variations RH <10% RH. Reducing these variations would further benefit the retention of the painting.

The following climate-technical improvements are proposed:

- Improvement of the physical properties of the building envelope (insulation)
- Local heating of the church and the baptistery
- Local mobile humidifier placed in the shrine so that the relative humidity in the room is kept under control. A disadvantage is that it is visible to the public.
- Improvement of the airtightness of the climate chamber and the baptistery

Further investigation will be performed.

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